Discontinuous cohesive laws for modelling mixed-mode delamination

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The cohesive-zone model has proven to be an effective tool to model non-linear fracture processes, such as the delamination of composite laminates in the case of large-scale bridging. According to this model, a fracture process zone – in the form of a cohesive interface – develops ahead of the crack front, where the new fracture surfaces are created and gradually separate from each other. Prior to complete separation, the fracture surfaces exchange interfacial stresses (or cohesive tractions), which depend on their relative displacements (or separations) [1].

Commonly adopted cohesive laws consist of traction-separation relationships, which can be subdivided into two ideal stages:

i. an elastic stage, where tractions increase up to a peak value, representing the response of the undamaged cohesive interface;
ii. a softening stage, where tractions decrease to zero, representing the progressive damage leading to fracture of the interface.

Often, linearly elastic response is assumed for the elastic stage. Instead, for the softening stage, many idealised trends have been proposed in the literature: from linear, or piece-wise linear, to exponential and power laws. In Ref. [2], we proposed using bilinear discontinuous cohesive laws to model the response of a double cantilever beam test specimen loaded with uneven bending moments (DCB-UBM) [3]. Very good agreement between the theoretical predictions and experimental results was obtained for tests conducted under pure fracture modes I and II.

Here, we show how the abovementioned discontinuous cohesive laws can be extended to I/II mixed-mode fracture conditions under the assumption that fracture modes are uncoupled and linear mixed-mode criteria govern crack onset and propagation [4]. As an illustrative example, the model is applied to the DCB-UBM under mixed-mode fracture conditions. The invariant J-integral is calculated along an internal (local) path and an external (global) path. Hence, theoretical predictions are obtained for the relative opening and tangential displacements at the crack tip, which qualitatively agree with experimental observations.

References

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